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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

AGARD ADVISORY REPORT No.294

Technical Evaluation Report on the Flight Mechanics Panel Symposium on Space Vehicle Flight Mechanics

(La Mécanique du Vol des Véhicules Spatiaux)

NORTH ATLANTIC TREATY ORGANIZATION

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ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.294

Technical Evaluation Report

on the

Flight Mechanics Panel Symposium

on

Space Vehicle Flight Mechanics

(La Mécanique du Vol des Véhicules Spatiaux)

by

Professor N.X.Vinh
Department of Engineering
College of Engineering
The University of Michigan
Aerospace Engineering Building
Ann Arbor, Michigan 48109-2140
United States

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- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

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Preface

In recent years, manned flights into low earth orbits have been made both for scientific study and for the placement of unmanned satellites into geosynchronous orbits and also into interplanetary orbits. Efforts of many nations are currently under way to place man into orbit on a semi-permanent basis through the use of a space station. At the same time, the aerospace industry worldwide is considering the extension from supersonic flight of advanced fighter aircraft to the hypersonic flight of a future aerospace plane.

To meet the challenges of the many technical problems to be solved in this new area, the Flight Mechanics Panel has sponsored its first symposium on Space Vehicle Flight Mechanics, held in Luxembourg, from November 13 to 16, 1989. The purpose of the symposium was to examine the flight mechanics of vehicles in space and in the upper layer of the atmosphere and to identify the areas of technology relevant to the Flight Mechanics Panel.

This Technical Evaluation Report evaluates the presentations and discussions in each of the five sessions of the symposium, draws relevant conclusions, and makes recommendations for future symposia in Space Flight Mechanics.

Préface

Un certain nombre de vols pilotés en orbite basse ont été effectués ces dernières années, d'une part pour faciliter la recherche scientifique et d'autre part pour permettre la mise sur orbite géosynchrone ou interplanétaire de satellites non-pilotés.

Plusieurs pays travaillent activement à la mise d'êtres humains en orbite de façon quasi-permanente en station spatiale. Parallèlement à ces activités, l'industrie aérospatiale internationale réfléchit à la transition du vol supersonique des avions de combat modernes au vol hypersonique du futur avion spatial.

Pour relever le défi posé par les multiples problèmes techniques qui sont à résoudre dans ce nouveau domaine, le Panel AGARD de la Mécanique du vol a organisé son premier Symposium sur la Mécanique du vol des véhicules spatiaux, à Luxembourg, du 13 au 16 novembre 1989. Le symposium a eu pour objectif d'étudier la mécanique du vol des véhicules dans l'espace et dans les couches supérieures de l'atmosphère et de définir les sujets technologiques susceptibles d'intéresser le Panel AGARD de la Mécanique du vol.

Ce rapport d'évaluation technique donne une appréciation des présentations ainsi que des discussions qui ont eu lieu lors de chacune des cinq séances du symposium. Il en tire des conclusions pertinentes et formule des recommandations concernant de futurs symposia sur la mécanique du vol spatial.

Technical Programme Committee

SPACE VEHICLE FLIGHT MECHANICS

1. INTRODUCTION

An AGARD Flight Mechanics Panel Symposium on "Space Vehicle Flight Mechanics" was held in Luxembourg, November 13-16, 1989. The purpose of the symposium was to examine the flight mechanics of vehicles in space and in the upper layer of the atmosphere and to identify the areas of technology relevant to the Flight Mechanics Panel.

In recent years, manned flights into low earth orbits have been made both for scientific study and for the placement of unmanned satellites into geosynchronous orbits and also into interplanetary orbits. Efforts of many nations are currently under way to place man into orbit on a semi-permanent basis through the use of a space station. At the same time, the aerospace industry worldwide is considering the extension from supersonic flight of advanced fighter aircraft to the hypersonic flight of a future aerospace plane.

To meet the challenges of the many technical problems to be solved in this new area, the Flight Mechanics Panel sponsored this first symposium on Space Vehicle Flight Mechanics. The meeting, held at the European Conference Centre, was attended by slightly over 100 persons from all the NATO nations.

2. REVIEW OF THE TECHNICAL PROGRAM

Over the four days of the symposium there were two keynote addresses and thirty technical papers from eight of the NATO nations: Belgium, Canada, France, Federal Republic of Germany, Italy, Netherlands, United Kingdom and the United States of America. The Appendix to this report contains the conference program.

This Technical Evaluation Report does not attempt to summarize and discuss each and every paper presented at this conference. Rather, it intends to bring out the key points from the presentations and discussions in each of the five sessions of the symposium in order to draw proper conclusions and make recommendations for future symposia in Space Flight Mechanics.

While the program covered all the aspects of space flight in the near earth environment, that is, from launch to orbital maneuvers and attitude control and including final recovery for a wide range of space vehicles from tethered satellite systems and flexible space structures to the space plane, it was clear that the intention of the technical program committee in the selection of the papers was to have a general discussion in order to bring out the key issues relevant to the Flight Mechanics Panel. Some papers were of a descriptive nature and they usually presented a major space program of the respective nation. Several papers discussed in depth the technical challenge of certain aspects of space flight and offered a solution which appeared to be satisfactory for the present state-of-the-art. Due to the interaction among several disciplines in AGARD in this important area of space flight mechanics, members from the Fluid Dynamics Panel, the Guidance and Control Panel, the Propulsion and Energetics Panel and the Structures and Materials Panel were invited to serve as co-chairmen in four of the five technical sessions of the symposium.

2.1 Keynote Addresses

At the opening ceremony, the two keynote addresses not only presented the views and perspectives on the future opportunities in space flight from Europe and from North America but also highlighted the future missions which challenge humanity and also the merging concepts in the development of space transportation systems which should ultimately lead to a cooperation among the NATO nations.

The first keynote address was delivered by Dr. Jan A. van der Bliek, the Director of AGARD. As AGARD Director, the speaker presented an excellent overview of the main technical and scientific challenges in Hypersonics, Propulsion, Structures and Materials which should be overcome for a successful realization of a human Space Transportation System in the 21st century. He mentioned the convergent goal of the various proposals for a partially or a fully re-usable system and pointed out the tremendous opportunities for transatlantic cooperation in the area of space technology in the 1990's and beyond. This dynamic address definitely set the tone for the conference.

The second keynote address was presented by Dr. K. H. Doetsch of Canada. By showing a series of slides, the speaker reviewed the space effort from the launching of the first satellite in 1957 to the present time as a continuing challenge. The technological challenges of the future were addressed and the author concluded that future missions should challenge humanity and in particular young scientists and engineers in the peaceful and systematic exploration of our solar system.

From both the keynote addresses, it was clear that the message conveyed to attendants of the symposium was that the space developments during the last thirty years have been remarkable and that a joint effort among nations should be made in order to face future challenges in space transportation and exploration.

2.2 Technical Sessions

The Symposium consisted of five technical sessions:

I. Launch and Recovery
II. In-Orbit Dynamics
III. Transatmospheric Flight
IV. Dynamic Aspects of Assembly and Operation in Space
V. Simulation and Flight Test.

Session II was subdivided into Session IIA-Trajectories, and Session IIB-Attitude Motion. It was the intention of the Program Committee to start each session with either a survey paper or a paper of general interest. Except for the paper No. 11 (Session IIA) which was rescheduled for presentation in Session V because of the late arrival of the two presenters, the make up of the sessions allowed good discussion and comparison among various proposals.

Session I.

This session consisted of seven papers. The session started with an excellent paper on "Flight Control Issues of the Next Generation Space Transportation Launch Vehicles" (Paper No. 3) given by Richard Powell of NASA Langley Research Center. Flight control issues for a two-stage, vertical-takeoff rocket system and for a generic aerospace plane concept to represent a horizontal takeoff air-breathing system were considered. Two flight control issues for the vertical takeoff system were uncovered. The first was the large gimbal angle range required for pitch trim when using parallel mated vehicles. The second was control during staging. Two issues were also identified for the air-breathing vehicle. The first was that since the drag losses are a significant fraction of the total ideal velocity required, the drag associated with trimming needs to be reduced. The second issue was that since the vehicle flies at high dynamic pressure for most of the ascent, the guidance system design to insure accurate insertion will be more difficult. The paper concluded that no flight control issue has been identified that would preclude the selection of either of these two classes of vehicle for the next launch vehicle.

Two papers from the FRG discussed numerical techniques for ascent and descent trajectory optimization. In Paper No. 4, K. H. Well presented an overview of the state-of-the-art of trajectory optimization of space vehicles during launch and reentry with special emphasis on the ARIANE V/HERMES system. It was mentioned that two improved versions of the widely used method of trajectory optimization by mathematical programming (TOMP), called PROMIS and TROPIC, were efficient and fast for the evaluation of the performances of reentry vehicles. Paper No. 7, presented by P. Strohmaier was motivated by the new mission requirements of having high cross ranges for the European space transportation concepts such as the ARIANE V/HERMES and the SAENGER/HORUS. Here, the new parameterized optimization program was speeded up from the TOMP package to an improved version appropriately named STOMP. The conclusion which can be drawn from these two papers was that efficient numerical methods for trajectory optimization were available to analyze three-dimensional reentry trajectories subject to heating constraints of future hypersonic vehicles.

The Paper No. 5 discussed the concept formulation and performance sensitivities of a two-stage space launch system with a highly efficient orbiter design. The study was initiated at the Flight Dynamics Laboratory of the USAF with contractual support from the Boeing Aerospace Company. The contribution from Italy was in the form of a proposal to achieve a geostationary orbit without any drift phase (Paper No. 6). The emergency reentry trajectories for Hermes were

discussed by Ph. Delattre and A. Wagner from Aerospatiale (Paper No. 8). The session concluded with a presentation of the space shuttle descent flight verification by simulation (Paper No. 9) by V. Nguyen from Rockwell International. The conclusion drawn from this paper was that simulation is an indispensable process. It provides a safe environment for the design of robust systems and, at the same time, reduces the cost of a flight test program.

Session II

On the second day, at the beginning of each of the morning session (IIA) and the afternoon session (IIB), the attendees were treated with short courses. The first one on "Astrodynamics and Trajectory Optimization" was given by Dr. J.-P. Marec and the second one on "Spacecraft Attitude Dynamics" by Professor V. J. Modi. Although the 30 minutes allocated to each of these presentations were too short, because of the clarity of the lectures and also because of the sophistication and the broad background of the audience, these overviews were enthusiastically received. The questions from the audience after these presentations mainly concerned the applications of the analytical theories to the actual trajectory design and the stability and control of the space vehicle.

With Paper No. 11 on Orbit Determination rescheduled for presentation in Session V, the morning session allowed more time for discussion. An interesting concept called SYCOMORES initiated by CNES (France) was discussed by a team from ONERA. This system proposed two communication satellites on geosynchronous orbits with the same high eccentricity and high inclination, but with diametrically opposite ascending nodes. The system would allow permanent coverage of a large part of Europe. Minimum fuel transfer for the system was presented. The morning session concluded with a paper on optimal aeroassisted transfer from Wright Research and Development Center and a paper on Hermes Rendezvous with the Space Station from MATRA.

The presentation and discussion in the afternoon session were equally successful. Besides Dr. Modi's lecture, four additional papers on attitude motion made up the session. A model of the perturbed spinning motion of the San Marco 5th spacecraft which was an aeronomy satellite in a low and nearly equatorial orbit with a relatively dense atmosphere and non-negligible gravity gradient and magnetic torques was discussed by Professor C. Arduini. Presented together in one session, Paper No. 17 discussing the accuracy of the Spacelab Instrument Pointing System (IPS), Paper No. 18 providing the design and evaluation of a visual display aid for human controllers in space, and Paper No. 19 detailing the NASA-ASI joint proposal for the Tethered Satellite System-1 (TSS-1), to be flow in 1991, emphasized the delicate operations of the attitude control and the maneuvering of linked satellite systems in orbit.

Session III

This half-day session on the third day was reserved for the presentations of four different concepts of an aerospace plane. The first one was the U.S. National Aero-Space Plane (NASP) presented by Dr. D. E. McIver who has been closely associated with the project. The decision to build the X-30, a flight research vehicle, has been scheduled for 1993, with a possible first flight in the late 1990's. The conclusion drawn was that the program is a very tough technical challenge, and the flight mechanics and flight systems elements are critical to vehicle performance and must be developed in parallel with other elements. A successful flight program of the X-30 will demonstrate the technology, and the experience gained will permit a rational plan for future aerospace planes. The United Kingdom has studied the Horizontal Takeoff and Landing (HOTOL) vehicle, a single stage space vehicle that uses a combination of airbreathing and rocket propulsion. The presentation was made by S. G. Furniss, the Deputy Technical Manager of the HOTOL program. A typical single-stage-to-orbit (SSTO) vehicle was used as a model. The conclusion was that with new and anticipated technologies, the ultimate goal of an SSTO is now believed to be possible. The SSTO vehicle presents a greater design challenge but will have significant cost advantages over the two-stage-to-orbit (TSTO) vehicle. Between these two presentations of single-stage vehicles, there was a discussion of the optimal trajectories for Saenger-type vehicles by J. Drexler from the Technical University of Munich. This system consists of two stages. The first stage is equipped with an airbreathing propulsion system. A rocket propulsion system is used for the second stage. It was shown that the constraints on dynamic pressure and load factor have a significant effect on the ascent performance, and the lifting capability of the upper stage is essential for achieving an ascent beginning at a small flight path angle at separation. The session concluded with a study on the optimal ascent trajectory of a typical SSTO vehicle by Aerospatiale. Again it was discovered that the constraint on the dynamic pressure dictates the design of the ascent trajectory and, as a consequence, the matching between aerodynamic and propulsive characteristics of the vehicle.

Session IV

On the last day, astronaut D. Walker led off the morning session with another overview type of paper describing the challenge of assembling the Space Station "Freedom" in orbit. The first phase for the construction is planned to start early in 1995 and the objective of this international program is to place a station in orbit and to be continuously manned by up to eight crew persons and used as a base for scientific research, space hardware development, space manufacturing and for satellite and transportation vehicle servicing.

Techniques for the assembling and for the deployment and control of flexible structures were discussed by speakers from Italy, Belgium and the United States. To be successful, the construction of large trusses in space in a relatively short time would require a highly controlled and well organized plan. While the use of robots offers the potential for reducing the number of EVA hours required for particular construction operations, the availability of humans greatly increases the reliability of complex construction tasks.

This session generated much interest in the audience. The questions addressed to the presenters ranged from the possible use of Saturn V for launching to questions of aluminum coating of the trusses and their orientation relative to the velocity vector. Astronaut Walker, with his experience, offered many constructive comments.

Session V

This concluding session, besides the presentation of Paper No. 11 on Orbit Determination by a well-qualified team from CNES, included papers on a real-time simulation facility for the development and qualification of a space-based manipulator, on the flight mechanics of Tethered Satellite Systems, and on the effects of low-bond number liquid motions on spacecraft attitude. An interesting presentation of the U.S. Department of Defense initiatives for testing the capabilities of space systems was made by Colonel W. A. Wisdom, USAF (Retired).

Before the closing remarks by the two co-chairmen of the Technical Program Committee, Mr. J. Levine and Dr. J.-P. Marec, and the chairman of the FMP, Mr. R. C. A'Harrah, the audience and in particular the session chairmen and this evaluator were invited to comment on the organization and the conduct of the Symposium.

3. CONCLUSIONS

Based on the interest shown by the participants from the first day to the last day, and especially on the comments in the closing session, AGARD and the Flight Mechanics Panel are to be complimented for organizing this conference on Space Vehicle Flight Mechanics. To this evaluator, this first symposium on space flight mechanics was very successful in meeting the following objectives:

— The emphasis on the meaning of the second A in AGARD to be "Aerospace" as mentioned in the keynote address by Dr. Van der Bliek. After the meeting, it appeared that Space Flight Mechanics is indeed a major area of relevance to the Flight Mechanics Panel.

— The demonstration that this topic is a multi-disciplinary subject. Considering problems such as the speed range getting into the largely neglected area of Hypersonics, the guidance of space vehicles in a rarefied atmosphere, the projected construction of flexible structures in space, the combination of robotics and human operations in a hostile environment, these problems concern all the Panels of AGARD.

— The assessment of the State-of-the-art in Space Vehicle Flight Mechanics. The participants and the speakers at the conference were from the top managerial and technical organizations of all of the NATO nations. The program covered all the key aspects of space applications. The general consensus was that the space flight of hypersonic vehicles and the construction of large space stations can be achieved with continuous effort and cooperation among the nations of the Alliance.

4. RECOMMENDATIONS

In this symposium, the various aspects of hypersonic flight and space operations were brought up for discussion for the first time by the Flight Mechanics Panel. This is a historical event and the effort should be continued.

For future symposia, since the topic is highly specialized, the program after this general overview should narrow its scope. The major topics of interest in the near future may be: Hypersonic Flight Mechanics, Orbital Transfer and Aeroassisted Technology, Space Dynamics of Large Structures. A large audience of between 100 and 200 persons can be expected if the program is well advertised in advance.

To arouse interest in space flight mechanics of winged vehicles, especially in the young generation of scientists and engineers, FMP should propose special courses on "Optimal Space Trajectories" and "Dynamics and Thermodynamics of Reentry Trajectories."

A question which has been brought up during the conference is the duplication of this activity with the annual IAF Congress which also has four sessions on Astrodynamics. To this evaluator, the objectives are different and with a frequency of organizing one symposium on Space Flight Mechanics every two years, with the purpose of assessing the current progress and projecting future research and development, actions taken by the FMP are complementary to other National and International programs of technical meetings.

FINAL PROGRAMME

FMP SYMPOSIUM

"SPACE VEHICLE FLIGHT MECHANICS"

13-16 November, 1989
LUXEMBOURG

Monday, 13 November

REGISTRATION
BRIEFING FOR SESSION CHAIRMEN, AUTHORS, INTERPRETERS
OPENING CEREMONY

1. KEYNOTE ADDRESS No. i - Ing. VAN DER BLIEK, NE, Director, AGARD

2. KEYNOTE ADDRESS No. ii - Dr. K. DOETSCH, NRCCC/CA

SESSION I - LAUNCH AND RECOVERY
Chairmen: P. HAMEL (GE), R. DECUYPERE (BE), FDP

3. Flight Control Issues of Next-Generation Space Transportation Launch Vehicles
   R. W. POWELL, J. C. NAFTEL, C. I. CRUZ
   NASA, Langley, US

4. Ascent and Descent Trajectory Optimization for Ariane V/Hermes
   C. JAENSCH, K. SCHNEPPER, K. H. WELL, DLR, GE

5. Advanced Launch Vehicle Configurations and Performance Trades
   P. R. GORD, M. E. STRINGER, K. J. LANGAN,
   Wright Research & Development Center, US

6. Possible Trajectory Profiles to Achieve the Geostationary Orbit Without Any Drift Phase
   G. VULPETTI, G. Di GENOVA, E. PEROZZI,
   L. REBOA, Telespazio, IT

7. Re-entry Trajectory Optimization and Control
   P. STROHMAIER, A. KIEFER, D. BURKHARDT, D. HORN
   MBB, GE

8. Trajectoires de Sauvegarde au Lancement d'Hermès.
   Conséquences sur les Trajectoires d'Ariane 5
   Ph. DELATTRE, AMD-BA, FR
   A. WAGNER, Aérospatiale, FR

9. Space Shuttle Descent Flight Verification by Simulation. A Challenge in Implementing Flight Control System Robustness
   V. H. NGUYEN, E. W. WOOSLEY, J. T. NISHIMI, T. H. PAYNE
   Rockwell International, US

Tuesday, 14 November

SESSION II - IN-ORBIT DYNAMICS

SESSION II A - TRAJECTORIES
Chairmen: A. FILISETTI (IT), P. VAN DEN BROEK (NE), GCP

10. Une introduction aux trajectoires spatiales naturelles et aux manoeuvres optimales (Overview)
    J.-P. MAREC, ONERA, FR

11. Calcul d'orbites
    P. EXERTIER, P. SENGENES, G. TAVERNIER
    CNES, FR

12. Optimisation de la mise à poste d'un couple de satellites sur des orbites géosynchrones, excentriques et inclinées
    J. BOUCHARD, C. AUMASSON, ONERA, FR

13. Non-coplanar Orbit Transfer Optimization for an Aeroassisted Sortie Vehicle
    R. B. NORRIS, H. A. KARASOPOULOS
    Wright Research & Development Center, US

14. Rendez-vous d'Hermès avec la Station Spatiale
    C. CHAMPETIER, M. CALDICHOURY, E. DESPLATS
    MATRA, FR

SESSION II B - ATTITUDE MOTION
Chairmen: M. GERADIN (BE), D. J. WALKER (UK)

15. Spacecraft Attitude Dynamics: Evolution and Current Challenges
    V. J. MODI, University of British Columbia, CA

16. A Model of the Perturbed Spinning Motion of the San Marco 5th Spacecraft
    C. ARDUINI, D. MORTARI, University of Rome, IT
    G. LA NEVE, Telespazio, IT
    A. de MICCO, Italian Air Force, IT

17. The Instrument Pointing System. Precision Attitude Control in Space
    A. WOELKER, R. HARTMANN, Dornier, GE

18. The Dynamics of Orbital Manoeuvering: Design of Visual Display Aids for Human Controllers
    S. R. ELLIS, A. J. GRUNWALD, NASA Ames, US

19. Dynamics and Dynamic Experiments in TSS-1 (Tethered Satellite System-1)
    S. BERGAMASCHI, University of Padua, IT

Wednesday, 15 November

SESSION III - TRANSATMOSPHERIC FLIGHT
Chairmen: L.M.B. da Costa CAMPOS (PO), W. B. de WOLF (NE), PEP

20. National Aero-Space Plane (NASP) - Flight Mechanics
D. E. McIVER, NASA HQ, US

21. Optimal Trajectories for Sanger-Type Vehicles
G. SACHS, R. BAYER, J. DREXLER
Technische Universitat Munchen, GE
H. KUCZERA, MBB, GE

22. Ascent and Descent Optimizations for an Air-Breathing Launch Vehicle
S. G. FURNISS, I. WALTERS, BA, UK

23. Optimisation globale des trajectoires de lanceurs aérobies
F. MARTEL, Aérospatiale, FR

Thursday, 16 November

SESSION IV - DYNAMIC ASPECTS OF ASSEMBLY AND OPERATION IN SPACE
Chairmen: S. R. METRES (US), P. SANTINI (IT), SMP

24. The Challenge of Assembling Space Station Freedom in Orbit
V. BRAND, D. WALKER, NASA-JSC, US

25. In-Space Construction and Dynamics of Large Space Structures
M. M. MIKULAS, Jr., NASA, Langley, US

26. A New Method for Tethered-System-Aided Space Station Assembly
S. C'ARDO, Aeritalia, IT
S. BERGAMASCHI, University of Padua, IT

27. Deployment of Large Flexible Space Structure
M. GERADIN, A. CARDONA, D. GRANVILLE
University of Liege, BE

28. Flexible Structure Control and Rigid Body Dynamics
V. B. VENKAYYA
Wright Research & Development Center, US

SESSION V - SIMULATION AND FLIGHT TEST
Chairmen: L. D. REID (CA), F. J. ABBINK (NE)

29. Effects of Low-Bond Number Liquid Motions on Spacecraft Attitude
J.P.B. VREEBURG, R. F. Van den DAM, NLR, NE

30. Flexible Space-Based Robot Modelling and Real-Time Simulation
J.J.M. PRINS, P. DIELEMAN, P.Th. L. M. Van WOERKOM
NLR, NE

31. Flight Mechanics Applications for Tethers in Space: Cooperative Italian - US Programs
F. BEVILACQUA, P. MERLINA, Aeritalia, IT
J. L. ANDERSON, NASA HQ, US

32 The Challenges of Space System Testing: A US/DoD Perspective
W. WISDOM, L. KEEL, J. MEANS, DoD, US

Discussion and Conclusion

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14. Abstract

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In recent years, manned flights into low earth orbits have been made both for scientific study and for the placement of unmanned satellites into geosynchronous orbits and also into interplanetary orbits. Efforts of many nations are currently under way to place man into orbit on a semi-permanent basis through the use of a space station. At the same time, the aerospace industry worldwide is considering the extension from supersonic flight of advanced fighter aircraft to the hypersonic flight of a future aerospace plane.

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Flight characteristics
Spacecraft
Spacecraft launching
Spacecraft recovery
Spacecraft simulation
Flight tests

To meet the challenges of the many technical problems to be solved in this new area, the Flight Mechanics Panel has sponsored its first symposium on Space Vehicle Flight Mechanics, held in Luxembourg, from November 13 to 16, 1989. The purpose of the symposium was to examine the flight mechanics of vehicles in space and in the upper layer of the atmosphere and to identify the areas of technology relevant to the Flight Mechanics Panel.

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